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MINERAL RESOURCES OF PENNSYLVANIA.

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This bulletin is designed to answer the questions commonly asked by school teachers and their pupils. For those needing fuller information, detailed reports are available on certain minerals.

The annual mineral production of Pennsylvania greatly exceeds that of any other State. The bulk of the production is coal, but portland cement, clay products, coke, petroleum, natural gas, stone, sand and gravel, slate and lime also yield large values, as shown by the accompanying table.

The minerals are discussed in the following order: fuels, structural materials, metals, non-metals.

Fuels.

Anthracite. Anthracite occurs in the following counties in Pennsylvania: Lackawanna, Luzerne, Carbon, Schuylkill, Northumberland, Dauphin, and Columbia. The total area underlain by hard coal is 484 square miles. Hard coal belongs to the same geologic age as the soft coal in western Pennsylvania. It is possible that coal beds have covered practically all of Pennsylvania, and that the rocks containing them were worn away, leaving a large area barren of coal, between the soft and hard coal fields. Originally, anthracite had approximately the same physical and chemical character as soft coal, but it has been changed by intensive folding of the rocks. Heat, pressure and movement, which accompanied the folding, drove out nearly all of the volatile matter in the coal, and now most of it is carbon. When the volatile matter was driven off the coal became hard, and brittle, and more difficult to ignite than soft coal.

Anthracite occurs in 10 to 15 beds; the number of beds varies locally. Anthracite is mined from beds 18 inches to 60 feet thick. The largest quantity of coal comes from beds 4 to 10 feet thick. Very little anthracite occurs in flat beds. Most of it is steeply pitching; some of it stands on end, and even is overturned. Mining is difficult because the coal has been crushed, faulted and broken. Surface water comes down into the mines through the cracks in the rocks and must be pumped out. Anthracite costs more than soft coal because of the difficulty of mining it, and because of the elaborate method of cleaning and sizing it for market. Much of the coal is mined by deep shafts, and all the impurities must be brought to the surface with the coal, to be separated on breakers, some of which cost $2,000,000.

Very little hard coal is used for manufacturing purposes. Practically all of it is used for domestic fuel , because it is practically smokeless, burns with a steady even heat, and does not require much attention.

Pennsylvania has produced 5,500,000,000 tons of anthracite. Active mining started in 1830, and has increased until the annual production ranges from 80,000,000 to 85,000,000 tons. There were originally 21,000,000,000 tons of anthracite; 16,000,000,000 tons remain in the ground, and approximately half of this coal, or 8,000,000,000 tons can be recovered. Most of the coal has come from the Northern field, near Wilkes-Barre and Scranton. As this field is gradually depleted, more coal will be shipped from the other fields. Anthracite will be mined for several hundred years but the coal will increase in price as the thicker and best beds are exhausted, and mining and preparation costs increase.

Bituminous. The main bituminous coal field of Pennsylvania covers much of the western fourth of the State. It lies west of Allegheny Mountain, or a line drawn through Meyersdale, Phillipsburg, and Emporium. Pittsburgh, Uniontown, Connellsville, Greensburg, Indiana, Punxsutawney, Clearfield, and Johnstown are the chief mining centers. Soft coal is found in thirty-two counties, and the field has an area of 14,200 square miles.

The bituminous coal beds of Pennsylvania are of Carboniferous age, and are confined to two systems, the Permian and Pennsylvanian.

The rocks of the bituminous coal field are folded into many anticlines and synclines, extending in a general northeast-southwest direction. The intensity of the folding increases eastward toward Allegheny Mountain.

Soft coal occurs in ten principal beds. Approximately twenty others are locally minable. Commercial coal beds range from 18 inches to 10 feet thick. The Pittsburgh bed has the most persistent average thickness, and ranges from 4 to 10 feet. The coals of the Freeport and Kittanning groups average less than 4 feet thick but are extremely valuable.

Most of the soft coal is mined by horizontal drifts, except in Greene and Washington counties, where the most valuable coal lies deep and is mined by vertical shafts or inclined slopes. Some deep shafts are also located in Fayette, Westmoreland, Indiana, and Cambria counties. There are approximately 3,500 coal openings in western Pennsylvania.

Pennsylvania has three kinds of soft coal: caking, noncaking, and cannel. The greater part of it is caking (softens and runs together when heated). The coal ranges from 57 to 85 per cent fixed carbon. The fixed carbon is lowest northwest of Pittsburgh, and highest in the Broadtop field.

Pennsylvania soft coal is used for domestic fuel, steam making, blacksmithing, metallurgical fuel, burning brick, tile and pottery, cement and lime, and coking. Coking of coal in the old type of beehive ovens involved an enormous waste. These old-type ovens are gradually disappearing, and by-products, or closed ovens, which recover the by-products, now make most of the coke. There are several hundred by-products of coal; some of the most useful and well known products are: illuminating gas, fuel gas, resin, naphtha, toluene used in making explosives, dyes, saccharin, medicines and perfumes; benzene, photographic chemicals, insecticides, nitric acid, ammonia, and ammonia compounds; pyridine, used in making dye, and disinfectants. The oil from by-product coking is made into dye, explosives, moth balls, paint, germicides, perfume, varnish, wood preservatives, and tar for road surfacing.

Pennsylvania has produced 4,935,000,000 tons of bituminous coal. The production rose from 464,826 tons in 1840 to 1,000,000 tons in 1850; 18,000,000 tons in 1880; 79,000,000 tons in 1900; 178,000,000 tons in 1918. Since 1923 the production has ranged from 131,000,000 to 150,000,000 tons. The principal producing counties are Fayette, Westmoreland, Washington, Allegheny, Cambria, Clearfield, Armstrong, Jefferson, and Somerset.

The original deposit of coal in beds over 18 inches thick was 75,959,339,000 tons. The amount mined out and lost is 5,823,263,000 tons. The recoverable coal is 44,762,747,000 tons.

Oil and gas. Oil and gas occur in commercial quantity only in the western and northern parts of the State. The principal gas-producing counties are, Greene, Washington, Fayette, Westmoreland, Allegheny, Butler, Armstrong, Indiana, Clarion, Jefferson, and Elk. Oil comes principally from Greene, Washington, Butler, Clarion, Venango, Warren, and McKean counties.

Oil and gas occur in the pore spaces of sandstone, in porous or fractured limestone, and locally in shale. Both of them are obtained by drilling with a weighted bit, attached to a cable. The bit is lifted and dropped by a drilling machine. The rock crushed by the fall of the bit, is then bailed out, and the bit is lowered farther into the hole. Oil and gas have been found at depths of less than a hundred feet, but the lasting wells are much deeper. At the present time the largest production is from depths of 1,000 to 3,000 feet. Test wells have been drilled; at McDonald, 7,248 feet; at Ligonier, 6,822, 6,989, 7,756 feet. At LaMont, near Kane, 7,900 (still drilling November 15, 1928); Marion Center, 7,002 feet; Punxsutawney, 5,750; Tidioute, 5,800 feet. Only one of these deep wells was productive.

Approximately 160,000 wells have been drilled in Pennsylvania. About 15 per cent of those drilled in proven territory were dry.

Oil and gas in Pennsylvania come mainly from sandstone of Lower Carboniferous and Upper Devonian age. Some has been found in

the Upper Carboniferous, or Coal Measures, and very little in the Lower Devonian and basal Silurian. There are between 35 and 40 producing sands which range from a few feet to 400 feet in thickness. The average oil and gas sand is less than 50 feet thick. These sands are named, and some of them can be recognized in several counties.

The oil industry began in 1859, at Titusville, with the drilling of the Drake well. Flowing wells were numerous in the early days, but the pressure behind the oil has been so decreased by the drilling of many wells that all of them are now pumped. The largest wells were in the McDonald pool, Washington County. In 1890 one well produced 740 barrels per hour. New wells now usually have an initial production of less than 50 barrels a day, and gradually decline to a few barrels. Occasionally a well produces 100 to 300 barrels a day for a short time. The average production per well per day is 1/3 barrel.

The first well drilled for gas was at Erie. The well produced at 1,200 feet. The town of Fairview (Butler County) was lighted by gas in 1873, and in the same year gas was piped to Titusville. Gas from the Murrysville pool (Westmoreland County) was piped to Pittsburgh in 1883. Now practically every large town in Pennsylvania west of Altoona uses natural gas. Wells have varied much in production. A few wells have come in at 50 to 60 million cubic feet a day; a large number initially produced from 1 to 30 million, but even these are rare; the average gas well in Pennsylvania produces a few thousand to a million cubic feet a day. Gas from new well flows into the line, but after the pressure declines, it must be sucked into a compressor station, which raises the pressure and drives the gas to its destination.

When oil leaves the well it is transported by pipe line, tank car, or truck to refineries. The oil is heated, and as the heat is increased various products are driven off: Benzene, naphtha, gasoline, kerosene, fuel oil, machine oils, lubricating oils, petrolatum (vaseline), greases, and paraffin wax.

Natural gas is used entirely for domestic heating and manufacturing purposes. Its intense regular heat makes it a desirable fuel in manufacturing glass and steel. It is used extensively for burning pottery, tile, and dishware. Natural gas has but two by-products - gasoline, which is condensed from the gas at the well, and carbon black.

The maximum production of oil in this State was 31,400,000 barrels in 1891. Production gradually declined until 1924 when the production was 7,486,000 barrels. It increased to 9,526,000 barrels in 1927. Oil will continue to be obtained by drilling in Pennsylvania for the next 100 years.

In some parts of the oil field, oil is being flushed out of the sand into wells by water, air, gas, and air-gas mixture under pressure. Only 15 to 25 per cent of the oil in some of the sands is recovered by pumping; approximately another 20 per cent can be obtained by other means. Mining of the oil sands may be undertaken within the next hundred years. Distillation of oil sands and carbonaceous shales in Pennsylvania is still further remote.

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Estimated Oil Resources.

	Barrels
Oil originally in ground	2,138,000,000
Produced 1859-1925	788,366,000
Future recovery by drilling	650,000,000
Left in ground after drilling	700,000,000

Natural gas production in Pennsylvania reached a maximum of 138 billion cubic feet in 1906; it decreased to 123 billion in 1918; 86 billion cubic feet in 1921, and increased to 107 billion cubic feet in 1926. Pennsylvania will continue to produce natural gas for many years.

Oil shale. Oil shales in Pennsylvania are confined to the western part of the State and to small areas in the Coal Measures. As a rule these areas consist of richly bituminous shale from 3 to 12 feet thick and are only a few acres in extent. These shales vary in richness, the best yielding about 1 barrel of oil to the ton of shale.

Structural Materials.

Clays and clay products. Pennsylvania, though second to Ohio, produces about 1/8th of all the clay products made in the United States. The clays and clay industries are scattered over the State, but are most abundant in the bituminous coal field, where clays occur with the coal beds. These clays are extensively used with the accompanying shales in making brick, tile, terra cotta, sewer pipe, etc. Some of the underclays are "flint clay" highly suited for making fire brick for furnace lining. In eastern and central Pennsylvania the abundant shales, some of which are hundreds of feet thick, are used for making brick. White clays and kaolin are found in a few places and are used for pottery, and as a filler for paper, paints, etc.

Sand, gravel and sandstone. Sand obtained loose or by grinding sandstone is used for making glass, for molding metals, for scouring and polishing, in mortar for building, and in concrete for roads and general structural purposes. Sands suitable for these purposes occur in many places in the State. Each purpose requires a special type of sand. The Oriskany sandstone near Mapleton Depot, Huntingdon County, is the principal source of glass sand. Gravel dredged on the Delaware near Morrisville and in the rivers near Pittsburgh is used for coarse aggregate in concrete. The Tuscarora quartzite, which is the principal mountain-making rock of Pennsylvania, is extensively used in making silica fire brick.

Sandstones are used throughout the State for building purposes. The Pottsville sandstone of western Pennsylvania is used more than any other for massive masonry, such as large bridges, and is quarried near Ellwood City, Neshannock Falls, and Curwensville. In the northern part of the State, certain sandstones have supplied a large trade in flagstone and are still used extensively for paving courts,

for flooring, and for garden walks. The largest flagstone operations in the State are at Meshoppen, Wyoming County.

Limestone and lime products. The Vanport limestone is the only one in the western end of the State that is quarried on a large scale for flux and cement. It occurs in a limited area between Beaver and Elk counties and commonly is 5 to 15 feet thick. Other limestone beds in the Coal Measures are used locally for crushed stone and agricultural lime but most of them are too thin to have commercial value.

The Helderberg limestone at the base of the Devonian is several hundred feet thick and outcrops in many valleys from Bedford and Fulton counties northeast to the Susquehanna between Williamsport and Duncannon, and from Schuylkill Haven to Stroudsburg. It is quarried in many places for local use, and in some places on a larger scale.

The pre-Silurian rocks are mostly dolomitic (magnesian) limestones but contain three beds of very pure limestone. These three beds are largely quarried for flux, lime, and cement making. In the Lehigh Valley the limestone grades over into shale, and the shaly limestone in the intermediate belt is the foundation of the great cement industry there. Limestones in southeastern Pennsylvania are used extensively as crushed stone for roads and concrete aggregate, and locally for building. White marble in Chester, Montgomery, and York counties is used for buildingstone.

Granite and related building stones. Various kinds of granitic rocks are quarried extensively in southeastern Pennsylvania for building stone. They range from coarse-grained granite occurring between Bethlehem and Reading to the banded gneisses in the Philadelphia district. Mica schist also is much quarried for local use near Philadelphia.

Trap, diabase, basalt, and rhyolite. All these igneous rocks are confined to southeastern Pennsylvania where they are fairly abundant. Trap or diabase is much used for road building. Very large quarries near Birdsboro and Quakertown crush hundreds of tons daily. At Coopersburg and St. Peters diabase is made into polished monument stock, called "black granite." Basalt and rhyolite having a permanent green or red color occur in South Mountain near Waynesboro, and are extensively used for roofing granules.

Serpentine and talc. Serpentine used formerly more than now for building stone occupies a narrow irregular belt in southeastern Pennsylvania. Talc occurring with the serpentine is quarried at Easton for paint making and other uses.

Slate. Slate occurs in two areas in Pennsylvania; one is a belt 7 to 13 miles wide extending across Northampton and Lehigh counties from near Delaware Water Gap to Slatedale west of Lehigh River. The other belt crosses Susquehanna River near the Maryland line. Pennsylvania is the largest producer of slate in the United States and produces a greater variety of slate products than any other State. Roofing and structural slate are the principal products. Structural slate includes slabs used for panels, shower stalls, vats, vaults, shelving, stairs, etc. Slate for electric switch boards, billiard tables, bulletin boards, blackboards, and school slates is produced extensively. Some of the quarries near

Pen Argyl are more than 500 feet deep.

Metals.

Iron. Iron ore mining began in Colonial days in southeastern Pennsylvania and spread over the State as limonite ores were found in many counties. This early development of iron smelting in small charcoal furnaces was the forerunner of the great iron and steel industry of today. Present mining is confined to magnetite ore in Lebanon and Chester counties. The magnetite mine at Cornwall is an open pit three-eighth of a mile long, several hundred feet wide, about 200 feet deep, and is the oldest continuously operated mine in North America. It was opened about 1740. The annual output approximates a million tons.

Copper and other metals. Some copper, gold, and silver are obtained as by-products in smelting the iron ore from Cornwall. Copper minerals occur in the South Mountains, but have not as yet been found in commercial quantity. Zinc was formerly mined at Friedensville in Lehigh County and occurs in a few other places. Lead has been mined in Sinking Valley in Blair County, and at Phoenixville, Chester County, but is not abundant. Chromite was once mined extensively in southern Lancaster County. Nickel was mined at Gap, Lancaster County, for some years. Manganese and aluminum minerals have been found in many places, but very little of it in minable quantity. Radium minerals have been found in a few places, but not as ores.

Mineral paints. Pennsylvania has long lead in the production of mineral paints and mortar colors, using the oxides and carbonates of iron, and black, yellow, and red shales. Present production is all from eastern Pennsylvania.

Non-metals.

Nonmetallic minerals. Rock salt occurs in northwestern Pennsylvania in rocks of Upper Silurian age, but is not mined. Salt brines were formerly used for the recovery of salt and bromine from wells in western Pennsylvania. Graphite has been mined in southeastern Pennsylvania from highly metamorphosed gneiss and limestone. Potash and phosphate minerals occur in Pennsylvania, and phosphate minerals have been mined a little. Asbestos, barite, and mica in small amounts have been recovered, but they are not being mined at present. Feldspar is being mined in Chester County on a small scale, and was formerly mined in Delaware County. It occurs in pegmatite veins. Southeastern Pennsylvania has furnished many minerals for cabinet specimens, and a few gems have been found.

Mineral Production.

The mineral production of Pennsylvania in 1926 was as follows:

Mineral Production of Pennsylvania in 1926. (U.S.G.S.)

Product	Quantity	Value
Cement ---------- bbls. --	[a]41,395,604	$[a]70,437,218
Clay products ----------	----------	[b]35,041,270
Clay, raw ---------- short tons ----	855,832	[c] 2,563,374
Coal:		
Anthracite ---------- do --------	84,437,452	474,164,252
Bituminous ---------- do --------	153,041,638	325,618,000
Coke ---------- do --------	21,922,976	[c]96,318,119
Copper[d] ---------- pounds -----	1,018,536	142,595
Gold[d] ---------- troy ounces ---	22	450
Iron ore:		
Sold to furnaces ---- long tons ----	1,088,634	2,483,056
Sold for paint -------- do --------	2,215	(c)
Lime ---------- short tons ----	794,196	6,303,312
Natural gas ---------- M cubic feet ----	107,089,000	50,040,000
Natural-gas gasoline ------- gallons ----	20,343,000	2,454,000
Petroleum ---------- barrels ----	8,961,000	31,930,000
Sand and gravel -------- short tons ----	12,873,953	11,695,218
Sand and sandstone (finely ground) - do -	(c)	(c)
Sand-lime brick ---------- thousands ----	(b c)	(b c)
Silica (quartz) -------- short tons ----	(c)	(c)
Silver[d] ---------- troy ounces ----	544	379
Slate ----------	----------	5,413,177
Stone ---------- short tons ----	[f]16,628,770	[f] 19,157,336
Miscellaneous[g] ----------	----------	14,064,462
Total value, eliminating duplications	----------	1,055,766,077

[a]Exclusive of natural cement, value for which is included under "Miscellaneous."

[b]Figures obtained through cooperation with Bureau of the Census.

[c]Value not included in total value for State.

[d]Copper, gold, and silver were recovered from pyritiferous magnetite. The quantity of such ore was 993,450 short tons in 1926; it is included in the figures shown for iron ore.

[e]Value included under "Miscellaneous."

[f]Exclusive of serpentine, value for which is included under "Miscellaneous."

[g]Includes minerals indicated by "a", "e", and "f" above.